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Conduction Disturbances After Correction of Tetralogy of Fallot: Are Electrophysiologic Studies of Prognostic Value?

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Late complete heart block may occur after correction of tetralogy of Fallot. Whether postoperative electrophysiologic studies can identify patients at risk of developing this conduction disturbance is unknown. In this study, 57 children who underwent electrophysiologic investigation after correction of tetralogy of Fallot were followed up for 1 to 13 (mean 6.5) years after the investigation.

One late death and two cases of late complete heart block occurred. The late death was due to ventricular arrhythmia and not to a conduction disturbance. The cases of late heart block occurred 2 and 5 years, respectively, after electrophysiologic study, and in both cases the patient had a prolonged HV interval; in one patient progressive lengthening of the HV interval could be demonstrated at two subsequent studies 1 year apart. Another five patients with a prolonged HV interval had normally conducted sinus rhythm up to 11 years after study. Atrial pacing at increasing rates (up to the occurrence of second degree atrioventricular block) during electrophysiologic study was the best means of predicting late heart block: of three patients with block below the bundle of His occurring at pacing rates <180/min, two developed late complete heart block.

Thus, electrophysiologic testing of the conduction system after correction of tetralogy of Fallot is useful in predicting late complete heart block and should be performed in patients with a history of transient heart block after surgery and in those with a prolonged PR interval.

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Late sudden death and syncopal episodes occur in a small percentage of patients after successful correction of tetralogy of Fallot. The causes are either ventricular arrhythmias or advanced conduction disturbances such as late complete heart block (1–3) or, on occasion, sinus node dysfunction (4). Precursors have been identified: a significant percentage of patients with numerous ventricular premature beats on routine electrocardiography die suddenly (2); on the other hand, transient complete heart block immediately after surgery, or bifascicular block with a long PR interval, may herald late complete heart block (5). To better identify patients at high risk, electrophysiologic studies may be indicated. Ventricular pacing studies have been performed to identify patients at risk for ventricular tachycardia and ventricular fibrillation (6); studies focusing on the condition system have also been published (7,8). The prognostic value of such studies, however, has not been demonstrated. We present here a report on 57 children who were studied after correction of tetralogy of Fallot and followed up for 1 to 13 years.

Methods

Study patients. From 1973 to 1985, 57 children underwent 59 electrophysiologic studies 2 months to 7 years after correction of tetralogy of Fallot (54 patients) or double outlet right ventricle (3 patients). Most studies (47 studies) were done 2 to 6 months after surgery. Two children were studied twice, at an interval of 1 and 11 years, respectively. The age of the children at study ranged from 1.5 to 20 years (mean 8). The main indications to perform a study were transient heart block after surgery in 8, a long PR interval ranging from 0.18 to 0.29 s in 11 and bifascicular block in 20. Twenty-three patients were part of a routine study that was previously published (7). Only seven children had a narrow QRS complex (no bundle branch block).

Study protocol. Details of the protocol have been previously published (7). Essentially, two electrode catheters were introduced percutaneously. A tripolar catheter electrode was placed at the atrioventricular (AV) junction to record the His bundle potential and a quadripolar catheter was placed in the high right atrium for atrial pacing and for the recording of high right atrial potentials. Conduction

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intervals (PA, AH, HV) were measured. The high right atrium was paced at progressively higher rates (for 30 s at each rate) until second degree AV block occurred.

Follow-up. The children were followed up for 1 to 13 years (mean 6.5) after the study. Children not attending our outpatient clinic were followed up by letters and questionnaires sent to their cardiologist requesting a 12 lead rest electrocardiogram (ECG) and information on survival, presence of syncopal episodes or rhythm disturbances.

Results

Electrophysiologic Studies

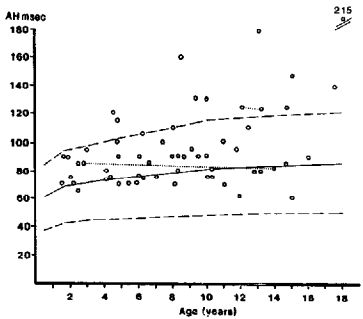
Conduction intervals (Fig. 1 and 2). These were abnormal in 13 children when compared with published normal values for age (9). A prolonged AH interval for age was recorded in 11 children (range 115 to 215 ms) and a prolonged HV interval in 7 (range 50 to 80 ms); 5 children had both AH and HV interval prolongation.

Pacing-induced AV block (Fig. 3 and 4.) Second degree AV block in response to fast atrial pacing occurred at the supra-His bundle level in 48 studies and at pacing rates of 102 to 260/min. Figure 3 shows individual data plotted against age. In seven patients the pacing-induced block occurred at rates lower than expected for age in our laboratory (7).

Pacing-induced second degree block at the infra-His level occurred in eight studies and at pacing rates of 128 to 226/min. In four studies (three patients), infra-His block was observed at a pacing rate <180/min. In three studies, the site of block could not be defined.

There was no correlation between hemodynamic measurements and conduction disturbances; the majority of patients (12 of 14) with one or more abnormal finding at electrophysiologic study had a good to excellent hemodynamic result.

Figure 1. AH intervals at electrophysiologic study in 57 children, plotted against age, with mean (**solid line**) and upper and lower limits of normal (**dashed lines**) according to Abella et al. (9). **Fine dotted lines** connect two subsequent measurements in the same patient.



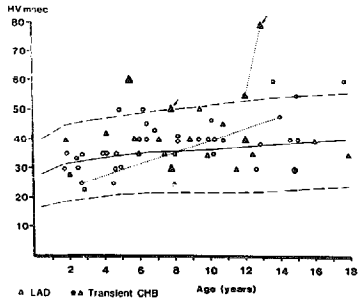
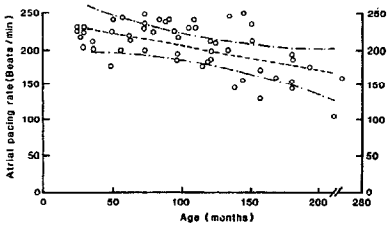


Figure 2. HV intervals at electrophysiologic study in 57 patients, plotted against age, with normal limits according to Abella et al. (9). Closed symbols indicate patients with a history of transient complete heart block (CHB). Arrows indicate the two patients who developed late complete heart block. LAD = left axis deviation on the surface ECG not present before surgery.

Follow-up

Five patients were lost to follow-up. The other 52 were followed up for a total of 346 patient-years (mean 6.7, range

Figure 3. Pacing rate at which second degree AV block occurred in 55 patients, plotted against age in months. Seven points are below the lower limit for age previously established in our laboratory (7).



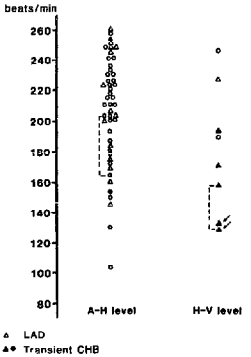


Figure 4. Atrial pacing rate at which second degree AV block occurred during electrophysiologic study in 57 patients either at the AH level (Wenckebach block) or at the HV level (2:1 block). **Dotted lines** connect two subsequent measurements in the same patient. **Arrows** indicate the two patients who developed late complete heart block (CHB). Other abbreviations as in Figure 2.

1 to 13). *There was one sudden death* 7 years after electrophysiologic study (11 years after surgery for double outlet right ventricle). A conduction disturbance was not the cause of death; the patient developed left ventricular dysfunction and ventricular arrhythmias, and ventricular tachycardia was documented shortly before death in the emergency room.

Fate of patients with conduction anomalies at AV node level. Among patients with evidence of AV node dysfunction only, either a prolonged AH interval (with a normal HV interval) or pacing-induced supra-His block at a rate lower than expected, none developed second or third degree heart block, but three showed progressive lengthening of the PR interval over a period of 1 to 7 years after electrophysiologic study (PR = 0.22, 0.25 and 0.32 s, respectively, at the last visit).

Fate of patients with conduction anomalies at His bundle level. Among seven patients with a prolonged HV interval, *two developed late complete heart block* 2 and 5 years, respectively, after electrophysiologic study. One of these patients had two studies at a 14 month interval and showed progressive lengthening of the HV interval; his case has been published in detail (10). The other patient had an HV interval only just above the upper limit of normal for age. The degree of HV lengthening thus did not predict late heart block. In particular, three patients with a definitely prolonged HV interval continued to have sinus rhythm with normal conduction up to 9 years after electrophysiologic study.

A better predictor of late heart block was the occurrence of infra-His block in response to atrial stimulation. Three patients showed block at the HV level during electrophysiologic study at an atrial pacing rate of only 128, 130 and 170/min, respectively. Two of these patients, the ones with block at the lowest pacing rates, developed late complete heart block 2 and 5 years, respectively, after the study. Both had a pacemaker implanted and survived.

In contrast, block at the HV level occurring with high pacing rates (>180/min) seems to have a good prognosis. None of the four patients with this type of response to atrial pacing developed major conduction disturbances during follow-up.

Discussion

Late sudden death and late heart block occur in a small percentage of patients successfully operated on for tetralogy of Fallot (1,2,5). Sudden death appears to be related to ventricular arrhythmias more often than to conduction disturbances (2,3). In the series presented here, the only late death was due to ventricular arrhythmia. Because we have not used ventricular stimulation programs in this study, we cannot comment on the prognostic value of electrophysiologic study with regard to ventricular arrhythmias.

Patients at risk of late heart block. Late complete heart block has long been recognized as a relatively rare but serious complication after repair of ventricular septal defect and tetralogy of Fallot (11,12). Patients at risk are mainly those who had transient complete heart block immediately after surgery (5). Both of our patients with late heart block did have transient block for a few days after surgery, but so did four others whose AV conduction remained normal. Right bundle branch block with left axis deviation, so called bifascicular block, was also suspected of being a precursor of late heart block (13), but there is now evidence that this is a benign condition (14) unless it is preceded by transient heart block (5). The association of bifascicular block and PR prolongation suggests trifascicular damage, but it is by no means diagnostic of it. Indeed, a long PR interval after cardiac surgery is often due to delay at the AV node level, and the surface ECG is not a reliable tool to diagnose trifascicular damage (15). Electrophysiologic studies aimed at detecting and localizing conduction disturbances have been undertaken by several groups (7,8,16), but the prognostic value of such studies has never been demonstrated.

Prognostic value of electrophysiologic testing. The main positive finding of this follow-up study is the prediction of late heart block. The occurrence of infra-His block during electrophysiologic study at low pacing rates was observed in three patients, and two developed complete heart block in the following years. Repeat study is also useful because it

may demonstrate progressive trifascicular damage not apparent on the surface electrocardiogram (increase in HV interval and decrease in rate at which infra-His block occurs). One of our patients received a pacemaker prophylactically on the basis of such progressive changes so that he remained asymptomatic when complete heart block developed 1 year later. HV prolongation alone, with normal response to pacing, does not seem to predict major late conduction disturbances; five such patients were followed up for up to 9 years and remained in sinus rhythm with normal conduction.

In the present study, AH interval prolongation was quite common, and Wenckebach block during atrial pacing occurred at rates lower than expected for age in seven patients. Such findings suggest AV node dysfunction. However, the prognosis appears to be favorable in all those who did not have associated HV prolongation. Although several of these patients show progressive lengthening of the PR interval on the surface ECG during follow-up, a higher degree of block has not occurred so far.

Prognostic value of surface ECG. The natural history of transient complete heart block after surgery for congenital heart disease was recently reviewed by Nishimura et al. (17) in a group of 22 patients. They found a high incidence of late heart block in patients whose surface ECG showed a QRS configuration (after return to sinus rhythm) different from QRS escape complexes during block. In our patients, QRS axis and configuration during transient AV block (from nonpaced ECG recordings) was identifiable in four; two had changes in QRS configuration after return to sinus rhythm. One of these developed late heart block; the other did not, but had evidence of HV conduction disturbance at electrophysiologic study. We agree that this may be a useful prognostic sign and should prompt electrophysiologic studies, as suggested by Nishimura et al. (7).

Conclusions. The present data indicate that electrophysiologic studies may be very helpful in detecting patients at high risk of late heart block after surgical correction of tetralogy of Fallot. Because the number of patients with this complication is small, more studies are needed to confirm our findings. The indication for such studies of the conduction system is either transient complete heart block after surgery or a prolonged PR interval, especially in the presence of bifascicular block. If abnormal His bundle conduction is detected, a repeat study 1 year later may demonstrate the progressive nature of some of the conduction disturbances and prompt the prophylactic implantation of a cardiac pacemaker.

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